Drilled Shaft Inspector CBT

Lesson 7 – Reinforcing Cage

Welcome to the Drilled Shaft Inspector Course. This is Lesson 7, Reinforcing Cage.

Learning Objectives

In this lesson, we will take a look at the following objectives:

- Describe cage construction
- Determine the circumference of a shaft and rebar cage and calculate the required number of side spacers.
- Explain how to assess the Contractor's compliance with cage construction/placement requirements
- Verify CSL tube placement and condition
- Identify the applicable 455 Specifications

Checklist

This slide shows a checklist of the main items for the reinforcing cage we need to inspect. Please spend some time reading this list. We will be covering these in this lesson.

Reinforcing Steel

Let's review this specification. Meet the reinforcing steel requirements of Section 415 which addresses the requirements for all reinforcing steel in the Department's projects. Ensure that reinforcing steel is in accordance with the sizes, spacing, dimensions, and details shown in the plans. We should note that on Federal Aid projects, steel must be made in the USA.

455-16 – Reinf. Steel Const. & Placement

Completely assemble and place as a unit the cage of reinforcing steel, consisting of longitudinal bars, ties, and cage stiffener bars, immediately after the Engineer inspects and accepts the shaft excavation and immediately prior to placing concrete. Tie all intersections of drilled shaft reinforcing steel with cross ties or "figure 8" ties. Use double strand ties or ties with larger tie wire when necessary. The Engineer will give final approval of the cage construction and placement subject to satisfactory performance in the field.

This picture shows an impressive reinforcing cage being assembled. This cage is for 12 foot diameter drilled shaft.

This is a typical shaft cross section that shows the reinforcement details for a particular project. The Inspector must verify and document the construction of the cage.

455-16 – Reinforcing Cage

Based upon the plans, the Inspector needs to check and compare:

- the steel Mill Certificate is provided
- the correct type and size bars are being used
- the correct number of bars is being used
- use of proper couplings and splices, if required
- proper lap, if required, on transverse bars
- proper bar spacing (longitudinal & transverse)
- the proper number and types of ties are used
- proper Cross Sonic Logging CSL tubes type and number are attached; and
- utilize appropriate methods for cutting extra length cage steel

Typically the minimum bar size used for longitudinal rebar is No. 8. Transverse bars may be as small as No.3 or No.4. The transverse bars are also called tie bars. The spacing between the bars, both longitudinal and transverse, needs to be of sufficient size to permit the flow of concrete and its aggregate.

The Structure Design Guidelines requires designers to provide a minimum clear distance between reinforcement of six inches to allow for proper concrete consolidation. Also shown in the slide is instrumentation for load tests. This will not be typical in production shafts but in tests selected for load testing. Note that if instrumentation is attached, it needs to be pre-tested before lifting and after placing.

\This image illustrates the ties. As seen before, the specifications require that all intersections that must be tied.

455-16.2 – Splicing Cage

Let's review this specification. If the bottom of the constructed shaft elevation is lower than the bottom of the shaft elevation in the plans, extend a minimum of one half of the longitudinal bars required in the upper portion of the shaft the additional length.

Continue the tie bars for the extra depth, spaced on 2 foot centers, and extend the stiffener bars to the final depth. The Contractor may lap splice these bars or use un-spliced bars of the proper length. Do not weld bars to the planned reinforcing steel unless shown in the Contract Documents.

Here is a recent change to the specifications. For drilled shafts supporting mast arms, cantilever signs, overhead truss signs, high mast light poles or other miscellaneous structures, if the shaft cleaning operations result in excavating below the required tip elevation, the reinforcing steel cage does not need to be extended.

The reinforcing steel cage may be spliced to rest on the bottom of the excavation or suspended in place from the top. This says that in shafts for miscellaneous structures, the steel cage does not need to be extended below the tip elevation indicated in the plans.

Spliced Cage

The pictures shows a reinforcing cage for a drilled shaft that was significantly extended. Note the extended longitudinal bars. Remember that a minimum of one half of the longitudinal bars must be extended.

This picture shows how splices are staggered. In this case the steel is spliced using mechanical couplers.

455.16.3 – Support, Alignment & tolerance

Use wheels or other approved noncorrosive spacing devices within 3 feet of the bottom, within 6 feet of the top, and intervals not exceeding 10 feet along the shaft to ensure concentric spacing for the entire length of the cage. Do not use block or wire type spacers. Use a minimum of one spacer per 30 inches of circumference of cage with a minimum of four at each level.

Side Spacers

The annular space refers to the area or space between the cage and the inside of the shaft, all around it’s circumference. As there is to be 6 inches of concrete cover over and around steel, the minimum annular space required is 6 inches.

This photo shows cage with side spacers that help maintain the annular space.

Spacers should be 12” in diameter, which allows for adjustment of the cage yet will provide the minimum clearance needed. If the spacers on your job are less than 12” in diameter, odds are you will need to watch placement carefully as the Contractor may not have the required 6” clearance. This slide shows a concrete spacer, which are not seen much anymore.

This photo is a light-wheel plastic spacer that just isn’t as sturdy as needed. These have a tendency to come apart and/or collapse. They are not acceptable. Notice how this one is already broken.

These spacers are heavy wheel plastic spacers have become very popular and are rugged enough for the job.

Number of Side Spacers

The specification sets forth the spacing of rows and the number of spacers per row to be used. To determine the total number of spacers we will need to know the length of the shaft and the circumference of the cage. With the length of the shaft you determine the number of rows that meets the specifications. With the circumference of the cage you will determine the number of spacers per row. The total number will be the number of rows times the number of spacers per row.

Circumference of a Circle

Let us review how to determine the circumference of a circle. The length of a circumference is given by pi times D, where D is the diameter of the circle. For pi you can use 3.142. Now, using this formula, calculate the circumference of a circle on a scratch piece of paper. When you have the problem calculated, select the continue button or Shift+N on your keyboard to see the answer.

The answer is 113.1 inches.

To determine the number of spacers required in a given row, we will need to determine the circumference of a rebar cage first. The diameter of the rebar cage will be the diameter of the shaft minus two; times the concrete cover. Determine the circumference of the rebar cage. The shaft has a diameter of 48 inches and the concrete cover is 6 inches. When you have the problem calculated, select the continue button or Shift+N on your keyboard to see the answer.

The diameter of the cage is 48 inches minus two times the cover. Since the cover I n FDOT drilled shafts is 6 inches, the diameter of the cage will be 48 inches minus 12 inches equals to 36 inches. The circumference length is then pi times 36 inches equals to 113.1 inches.

Now, work out this exercise to determine the total number of spacers. The diameter of the cage is the same of the previous exercise, 48 inches. The diameter of the cage is

36” for which we already computed a circumference of 113.1 inches. Determine the number of spacers required. When you have the problem calculated, select the continue button or Shift+N on your keyboard to see the answer.

First row could be within 3 ft from the bottom. Let’s start our first row at 1.5 ft from the bottom. Then let us put a row every 10 ft going up. This will give us rows at 1.4, 11.5, 21.5, 31.5 41.5 and 51.5 ft. Since the last row is within 6 ft from the top we are OK right there. If this shaft had been, for example, 60 ft., we would have had to add another row to comply with having one row within 6 ft. from the top. So we need 6 rows.

The number of spacers per row is: the circumference divided by 30 inches rounding up to next whole number, equals to 113.1 divided by 30 equals to 3.77 and rounding up is 4 spacers per row. Total number of spacers equals to 4 times 6 equals 24.

455.16.3 – Support, Alignment & tolerance

For the bottom of the shaft the specifications requires the following: Provide spacers at the bottom of the drilled shaft reinforcing cage as required to maintain the proper position of the cage

Let’s Review this specification. Check the elevation of the top of the steel cage before and after placing the concrete. If the rebar cage is not maintained within the specified tolerances, correct it as directed by the Engineer. Do not construct additional shafts until modifying the rebar cage support in a manner satisfactory to the Engineer.

Typical Standoffs (Bottom Spacers)

This picture shows the standoffs being made. You can see they are being molded in regular concrete cylinder molds, which are 12” in height. This picture shows the finished standoffs.

This picture shows the manufactured bottom spacers on the cage.

Side Spacers & Standoffs

This picture shows the proper spacers and bottom support on a cage being lowered into a shaft. There are manufactured bottom spacers**,** but they typically do not meet the bottom spacing requirements. They usually provide 3 inches bottom spacing which is less than the 6 inches required. In this picture, it shows a plastic bottom spacer in which an insert has been added to meet the spacing requirements.

Reinforcement Storage

The reinforcement should not be stored in contact with soil. It should be kept away from oil or other deleterious materials, and the cage should be properly supported during storage & lifting.

Reinforcement Cage handling

Here is an example of a reinforcing cage improperly handled. The cage is picked up essentially at one point and is distorted almost 90 degrees.

The Inspector should observe and document how the cage is picked up; was it in accordance with the plan details or specifications; did it stay together or did bars shift out of place. It is important that the cage remains straight, so that the specified concrete cover is achieved. A permanent deformed cage would necessitate contacting the Project Administrator.

The cage in this photo is picked up at four points (using the ground as one point of support) and remains quite straight and undistorted. The cage also used several internal stiffeners to assist in the pick-up process. These were removed as the cage was placed in the excavation**.**

Common Reinforcement Cage Issues

This picture shows a shaft with “J” bars in the reinforcement. This type of design may create problems during construction since the space results very limited later on for the pouring operations. The Department has been increasing, in the last few years, the minimum shaft diameters to prevent construction problems related to overcrowding of elements. To prevent this type of problems, currently the minimum shaft diameter for bridges is 42” for redundant foundations and 48” for non-redundant foundations.

Another issue may result with “hook bars” particularly when dealing with temporary casing that the contractor needs or wants to extract.

Cross-hole Sonic Logging tubes

CSL stands for Cross Sonic Logging which is a type of integrity testing in drilled shafts. In the last lesson we will present details of this test. All shafts are required to have access tubes for this test, even though not all the shafts may be required to be tested. The tubes allow access to the CSL equipment sounds. They may also be used for other types of integrity testing such as gamma and thermal integrity testing.

455-16.4- CSL Tubes

Install CSL access tubes full length in all drilled shafts from the tip of shaft to a point high enough above the top of the shaft to allow cross-hole-sonic-logging testing, but not less than 30 inches above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. ALL shafts require the installation of CSL access tubes. This does not mean that all the shafts will be tested, but by installing tubes in all the shafts, it will allow the engineer later on to select any shaft for testing.

Access tubes from the top of the reinforcing cage to the tip of the shaft shall be NPS 1-1/2 Schedule 40 black iron or black steel pipe (not galvanized). Access tubes above the top of the reinforcing cage may be the same black iron or black steel pipe or Schedule 80 PVC pipe. Ensure that the CSL access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that the inside of the tube remains flush.

Note, in the specification NPS means Nominal Pipe Size.

Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage. Repair or replace any unserviceable tube prior to concreting.

Provide the following number (rounded up to the next whole number of tubes) and configuration of cross hole sonic logging access tubes in each drilled shaft based on the diameter of the shaft. For shaft diameters of up to 48 inches, provide 4 tubes at 90 degrees apart. For shaft diameters greater than 48”, provide a tube per foot of shaft diameter, rounding up to the next whole number.

Insert simulated or mock probes in each cross-hole-sonic access tube prior to concreting to ensure the serviceability of the tube. It is very important that the inspector ensures the contractor verifies the condition of the CSL tubes prior to concreting. Fill access tubes with clean potable water and recap prior to concreting. Repair or replace any leaking, misaligned or damaged tubes as in a manner acceptable to the Engineer prior to concreting.

Here is a recent change in the specifications that only applies for drilled shafts in miscellaneous structures. For drilled shafts supporting mast arms, cantilever signs, overhead truss signs, high mast light poles, or other miscellaneous structures, if the shaft cleaning operations result in excavating below the required tip elevation, the CSL tubes do not need to be extended.

If the reinforcing steel cage is suspended in place from the top rather than resting on the bottom of the excavation, clearly mark the top of shaft location on each tube. Basically for miscellaneous structures it is not necessary for the contractor to extend the reinforcement or the CSL tubes below the tip elevation indicated in the plans.

This slide shows a drilled shaft cross section in which the CSL access tubes are indicated. Cages are typically assembled in advance so you should have time to check diameters and lengths of the reinforcing cage and the CSL tubes. It is easier to fix errors and omissions prior to construction.

This slide shows a photo of a reinforcing cage with CSL tubes installed on a cage. Just as with rebar, these tubes need to be properly secured to the cage in accordance with the plan details or specifications. Access tubes must be firmly secured to the cage and should be placed inside the cage.

The tubes should extend from the bottom of the shaft to at least 30 inches above the top of the shaft, or the ground surface or water surface, whichever is higher. The access tubes should be filled with clean water and capped prior to concrete placement.

700-010-84 Inspection Form

The Inspector is to compete the Drilled Shaft Log portion related to the Reinforcing Cage, which is located on page 2 of the Drilled Shaft log. In addition, the inspector is to complete form 700-010-33, presented next. As mentioned earlier, the Inspector must check the constructed cage against the plans and if everything matches, he would check “Yes”. If not check “No” and place your comments in the “Comment” section below.

Remember to check for:

1. Proper # Vertical Bars – does the number of bars and their size, match the plans?
2. Proper # Horizontal Bars- does the number of bars and their size match the plans?
3. Side Standoffs (spacers) - is the correct number (total and per row) in place?
4. Bottom Standoffs - does the number and the clearance from bottom of shaft to bottom of cage match the plans?
5. Epoxy Condition - Epoxy is no longer used so that should be N/A.

6. Ties & Connections - are the ties (number or percentage) as specified in the plans. Use Comments section to provide any details.

In addition to do the “checkings” in form 700-010-84, the Inspector needs to compete the Drilled Shaft Reinforcement/Spacers Log to document CSL access tubes, spacers used, reinforcement diameters and length and extensions used. In this form the inspector documents the reinforcement, CSL and spacers observed. Items such as, bar size, lengths, CSL number of tubes, distances between spacer’s rows, etc, are recorded in this form.

The “Cage”

Here is a completed cage, being lifted.

Topics covered

In this lesson we have performed the following:

- Describe cage construction
- Determine the circumference of a shaft and rebar cage and calculate the required number of side spacers.
- Explain how to assess the Contractor’s compliance with cage construction/placement requirements
- Verify CSL tube placement and condition
- Identify the applicable 455 Specifications

End of Lesson

This is the end of lesson 7. Please continue to the next lesson.